

## TITLE OF THE INVENTION

### DISPLAY DEVICE

## BACKGROUND OF THE INVENTION

5

### 1. Field of the Invention:

[0001]

The present invention relates to a display device which utilizes an emission of electrons into a vacuum which is defined  
10 between a face substrate and a back substrate, and more particularly, to a display device which can arrange, with high accuracy, cathode lines having electron sources and control electrodes which control a quantity of electrons led or emitted from the electron sources and can exhibit stable display  
15 characteristics by holding a vacuum between the front substrate and the back substrate.

[0002]

### 2. Description of the Related Art

As a display device which exhibits the high brightness  
20 and the high definition, color cathode ray tubes have been widely used conventionally. However, along with the recent request for the higher quality of images of information processing equipment or television broadcasting, the demand for planar displays (panel displays) which are light in weight and require  
25 a small space while exhibiting the high brightness and the high

definition has been increasing.

[0003]

As typical examples, liquid crystal display devices, plasma display devices and the like have been put into practice.

5 Further, particularly, as display devices which can realize the higher brightness, it is expected that various kinds of panel-type display devices including a display device which utilizes an emission of electrons from electron sources into a vacuum (hereinafter, referred to as "an electron emission type  
10 display device" or "a field emission type display device") and an organic EL display which is characterized by low power consumption will be commercialized.

[0004]

Among such panel type display devices, as the  
15 above-mentioned field emission type display device, a display device having an electron emission structure which was invented by C. A. Spindt et al, a display device having an electron emission structure of a metal-insulator-metal (MIM) type, a display device having an electron emission structure which utilizes an electron  
20 emission phenomenon based on a quantum theory tunneling effect (also referred to as "surface conduction type electron source), and a display device which utilizes an electron emission phenomenon observed with a diamond film, a graphite film and carbon nanotubes and the like have been known.

25 [0005]

The field emission type display device includes a back substrate which forms cathode lines having electron-emission-type electron sources and control electrode on an inner surface thereof and a front substrate which forms an anode and a fluorescent material on an inner surface which faces the back substrate, wherein both substrates are laminated to each other by inserting a sealing frame between inner peripheries of both substrates and the inside thereof is evacuated. Further, to set a distance between the back substrate and the front substrate to a given value, distance holding members are provided between the back substrate and the front substrate.

[0006]

The distance holding members for holding the distance between the back substrate and front substrate are formed of a thin plate made of glass or ceramics and are provided in an erected manner at positions away from the pixels. Here, as conventional examples of the display device provided with such distance holding members, Japanese Unexamined Patent Publication 326306/1995 and Japanese Unexamined Patent Publication 338528/2001 can be named.

#### SUMMARY OF THE INVENTION

[0007]

Fig. 1(a) and Fig. 1(b) are schematic explanatory views of the overall constitution of a field emission type display

device, wherein Fig. 1(a) is a plan view as viewed from a front substrate side and Fig. 1(b) is a side view which is obtained by viewing Fig. 1(a) in the direction of an arrow A. In Fig. 1(a) and Fig. 1(b), numeral 1 indicates a back substrate, numeral 2 indicates a front substrate, numeral 3 indicates an outer frame and numeral 4 indicates an exhaust pipe (in a sealed state). At the back substrate 1, on an insulating substrate which is preferably made of glass or ceramics such as alumina, a plurality of cathode lines having electron sources extend in one direction (x direction) and are juxtaposed in another direction (y direction). Above these cathode lines, a plurality of control electrodes which are insulated from the cathode lines, extend in the y direction and are juxtaposed in the x direction are provided. Further, the outer frame 3 is interposed between outer peripheries of opposing back substrate 1 and front substrate 2 which define the distance therebetween and the inside which is surrounded by the outer frame 3 is evacuated and sealed in vacuum. The front substrate 2 is stacked on the back substrate 1 in the z direction. After laminating the back substrate 1 and the front substrate 2 by interposing the outer frame 3 therebetween, the inside of the outer frame 3 is evacuated using an exhaust pipe 4 and the inside of the outer frame 3 is sealed at a given degree of vacuum.

[0008]

Fig. 2(a) and Fig. 2(b) are schematic explanatory views

of a constitutional example of the back substrate which constitutes the display device shown in Fig. 1(a) and Fig. 1(b), wherein Fig. 2(a) is a plan view as viewed from an upper side in the z direction and Fig. 2(b) is a side view which is obtained by viewing Fig. 2(a) in the direction of an arrow B. Numeral 5 indicates cathode lines, numeral 6 indicates plate-member control electrodes, numeral 7 indicates electrode pressing members, and numeral 8 indicates an exhaust hole. In Fig. 2(a) and Fig. 2(b), numerals which are equal to those in Fig. 1(a) and Fig. 1(b) indicate identical functional parts. Here, the exhaust pipe shown in Fig. 2(a) and Fig. 2(b) is shown in a state before sealing. The plate-member control electrodes 6 are configured by arranging a large number of strip-like electrode elements having electron passing apertures in parallel. These plate-member control electrodes 6 are proposed by inventors of the present invention in the course of developing the present invention and do not constitute the prior art.

[0009]

On an inner surface of the back substrate 1, cathode lines 5 are mounted. The cathode lines 5 extend in the x direction on the back substrate 1 and are juxtaposed in a large number in the y direction which crosses the x direction. The cathode lines 5 are patterned by printing a conductive paste including silver or the like. End portions of the cathode lines 5 are pulled outside the outer frame 3 as cathode line pullout lines

5a. On the cathode lines 5, electron sources such as metal-insulator-metal (MIM) type electron emission elements, electron emission structure (also referred to as surface conductive electron source) elements which make use of an electron emission phenomenon generated by a quantum theory tunneling effect, diamond films, graphite films or carbon nanotubes or the like (not shown in the drawing) are formed. [0010]

The plate-member control electrodes 6 shown in Fig. 2(a) and Fig. 2(b) are manufactured in a separate step as separate parts. Further, the plate-member control electrodes 6 are arranged above (front substrate side) and in the vicinity of the cathode lines 5 having electron sources and are fixed to the back substrate 1 using electrode pressing members 7 which are provided outside the display region and inside the outer frame 3 and are formed of an insulating body made of glass material or the like. Pullout lines are connected to the plate-member control electrodes 6 in the vicinity of the electrode pressing members 7 or in the vicinity of the outer frame 3 and these pullout lines are pulled out to an outer periphery of the display device (not shown in the drawing). Then, pixels are formed in a matrix array on crossing portions between cathode lines 5 and the plate-member control electrodes 6 and the above-mentioned display region is formed on the pixels which are arranged in a matrix array. Here, it is also possible to make the outer

frame 3 have the function of the electrode pressing member 7.

[0011]

Here, an emission quantity (including ON/OFF) of electrons from the electron sources formed on the cathode lines 5 is controlled in response to the potential difference generated between the cathode lines 5 and the plate-member control electrodes 6. On the other hand, the front substrate 2 shown in Fig. 1(a) and Fig. 1(b) is made of an insulating material having optical transmissivity such as glass, wherein the front substrate 2 includes anodes and phosphors on an inner surface thereof. The phosphors are formed corresponding to pixels formed at the crossing portions of the cathode lines 5 and the plate-member control electrodes 6. Further, a light shielding layer (black matrix) is provided around the phosphors.

15 [0012]

Vacuum is created by evacuating air from the inside of the front substrate 2 and the back substrate 1 which is sealed by the outer frame 3 from the exhaust hole 8 through the exhaust pipe 4 so that the degree of vacuum of  $10^{-2}$  to  $10^{-5}$  Pa, for example, is obtained. Electron passing apertures not shown in the drawing are formed in each crossing portion of the plate-member control electrode 6 and the cathode line 5 so as to allow electrons emitted from the electron source formed on the cathode line 5 to pass therethrough toward the front substrate side (anode side). It is necessary to mount the plate-member control electrodes 6 on

the back substrate 1 on which the cathode lines 5 are formed and over the whole display region with a given gap with respect to the cathode lines 5.

[0013]

5           The distance holding members are usually formed of a large number of thin glass plates or the like and are arranged vertically (z direction) between the plate-member control electrodes 6 such that they form partition walls between the back substrate and the front substrate. Accordingly, the assembling step of the  
10 distance holding members requires a delicate and sophisticated expertise. Further, a stress which copes with a vacuum pressure is applied to the distance holding members from the front substrate and the back substrate and hence, unless a plurality of the distance holding members are arranged to receive the stress  
15 uniformly, the stress concentration occurs on some distance holding members thus giving rise to the rupture of the distance holding members per se, the front substrate or the back substrate.

[0014]

          In the invention disclosed in the above-mentioned Japanese  
20 Unexamined Patent Publication 326306/1995 which provides one of countermeasures to cope with such a drawback, a material which is obtained by applying a paste having silver as a main component as a resilient material between distance holding members and a substrate and baking the paste, or an inorganic adhesive having  
25 low Young's modulus ("ARON Ceramics", a product of Toa Gosei



Kagaku Ltd. in the embodiment) is used. Further, in the above-mentioned Japanese Unexamined Patent Publication 338528/2001, conductive frits are interposed between the distance holding members and the substrates. However, the  
5 Young's modulus which these materials possess as the resilient material is not considerably large (flexible) compared to that of the glass plate or the ceramics plate which constitutes the distance holding members and hence, a stress dispersion effect is limited. Particularly, when a conductive paste is  
10 used on the back substrate on which cathode lines and control electrodes are formed, there arises a problem with respect to insulating property.

[0015]

Further, mounting of the distance holding members requires  
15 the arrangement of the distance holding members between the back substrate and the front substrate with high accuracy and with uniformity and, at the same time, it is necessary to make the stress attributed to atmospheric pressure uniformly applied to a large number of distance holding members. However, in the  
20 above-mentioned prior art, only a viewpoint that the distance holding members are mounted in an erected manner between the back substrate and the front substrate is taken into account. That is, the prior art does not taken account of the mounting of the distance holding members in the display device which  
25 arranges control electrodes between the back substrate and the

front substrate.

[0016]

Accordingly, it is an object of the present invention to mount a large number of distance holding members with high accuracy in a display device which arranges control electrodes between a back substrate and a front substrate. Further, it is another object of the present invention to provide a highly reliable display device by making a stress attributed to atmospheric pressure substantially uniformly applied to a large number of distance holding members so as to suppress the rupture of the distance holding members, the back substrate or the front substrate.

[0017]

To achieve the above-mentioned objects, in the present invention, with respect to a large number of distance holding members which are arranged in an erected manner between a back substrate and a front substrate and hold a distance between both substrates, at portions thereof which are brought into contact with the above-mentioned back substrate and/or front substrate, buffering/fixing materials which have high resiliency to substantially uniformly disperse an atmospheric pressure applied thereto from the back substrate and the front substrate and each of which is constituted of a buffer material and an adhesive are interposed, and the distance holding members are fixed between the back substrate and the front substrate due

to heat treatment and pressurizing steps.

[0018]

Due to such a constitution of the present invention, the buffer material is fixed such that the pressure is applied to many distance holding members in the above-mentioned heat treatment and pressurizing steps. As a result, it is possible to suppress the rupture of the distance holding members, the back substrate or the front substrate. To explain the typical constitutions of the present invention, they are as follows.

10 [0019]

(1) A display device comprises:

a front substrate forming anodes and phosphors on an inner surface thereof;

a back substrate which forms a plurality of cathode lines which extend in one direction and are juxtaposed in another direction which crosses the one direction and have electron sources and a plurality of control electrodes which cross the cathode lines in a non-contact manner within a display region, extend in the above-mentioned another direction, are juxtaposed in the above-mentioned one direction, and have electron passing apertures which allow electrons from the electron sources to pass therethrough on an inner surface thereof, the back substrate being arranged to face the front substrate in an opposed manner with a given distance therebetween; and

25 distance holding members being sandwiched between the

front substrate and the back substrate in an erected manner and holding a distance between the front substrate and the back substrate to a given distance; wherein

5 a buffering/fixing material is provided between at least one of the front substrate and the back substrate and the distance holding members, and the buffering/fixing material is formed by mixing an adhesive to a highly resilient material which has high resiliency at the time of assembling and dissipates in a baking step.

10 [0020]

(2) In the above-mentioned constitution (1), the control electrodes are constituted of plate-members which are formed by arranging a plurality of strip-like electrode elements in parallel.

15 (3) In the above-mentioned constitution (2), the display device includes an outer frame which is interposed between the front substrate and the back substrate such that the outer frame surrounds the display region to hold the given distance, and

the display device further includes electrode pressing members which fix both end regions of the strip-like electrode elements which constitute the control electrodes to the back substrate outside the display region and the inside the outer frame.

[0021]

25 (4) In the above-mentioned constitutions (1) to (3), a

low-temperature decomposing foamed resin is used as the above-mentioned highly resilient material.

[0022]

(5) In the above-mentioned constitution (4), urethane is  
5 used as the above-mentioned low-temperature decomposing foamed resin.

(6) In any one of the above-mentioned constitutions (1) to (5), a low melting-point glass is used as the adhesive.

[0023]

10 (7) A display device comprises:

a front substrate forming anodes and phosphors on an inner surface thereof;

a back substrate which forms a plurality of cathode lines which extend in one direction and are juxtaposed in another  
15 direction which crosses the one direction and has electron sources and a plurality of control electrodes which cross the cathode lines in a non-contact manner within a display region, extend in the above-mentioned another direction, are juxtaposed in the above-mentioned one direction, and have electron passing  
20 apertures which allow electrons from the electron sources to pass therethrough on an inner surface thereof, the back substrate being arranged to face the front substrate in an opposed manner with a given distance therebetween; and

distance holding members being sandwiched between the  
25 front substrate and the back substrate in an erected manner and

holding a distance between the front substrate and the back substrate to a given distance; wherein

a buffering/fixing material is provided between at least one of the front substrate and the back substrate and the distance  
5 holding members, and the buffering/fixing material is formed by mixing an adhesive to a highly resilient material which has high resiliency and is present as a reinforcing material after a baking step.

[0024]

10 (8) In the above-mentioned constitution (7), the control electrodes are constituted of plate members which are formed by arranging a plurality of strip-like electrode elements in parallel.

(9) In the above-mentioned constitution (8), the display  
15 device includes an outer frame which is interposed between the front substrate and the back substrate such that the outer frame surrounds the display region to hold the given distance, and

the display device further includes electrode pressing members which fix both end regions of the strip-like electrode  
20 elements which constitute the control electrodes to the back substrate outside the display region and inside the outer frame.

[0025]

(10) In the above-mentioned constitutions (7) to (9),  
heat-resistant fibers are used as the above-mentioned highly  
25 resilient material.

[0026]

(11) In the above-mentioned constitution (10), aramid-based fibers are used as the heat-resistant fibers.

[0027]

5 (12) In any one of the above-mentioned constitutions (7) to (11), a low melting-point glass is used as the adhesive.

[0028]

Due to the above-mentioned respective constitutions, the atmospheric pressure which is applied to a large number of distance holding members which are arranged between the back substrate and the front substrate in an erected manner becomes substantially uniform so that it is possible to obviate the rupture of the back substrate, the front substrate or the distance holding members. Here, as the highly resilient material, besides the materials described above, a plastic material formed of foamed polyethylene or acetate fibers can be used.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1(a) and Fig. 1(b) are schematic explanatory views showing the overall constitution of a field emission type display device.

20

Fig. 2(a) and Fig. 2(b) are schematic explanatory views showing a constitutional example of a back substrate which constitutes the display device shown in Fig. 1(a) and Fig. 1(b).

25 Fig. 3(a) and Fig. 3(b) are explanatory views showing a

first embodiment of the display device according to the present invention.

Fig. 4 is an enlarged view of a D portion of Fig. 3(b).

Fig. 5 is a schematic explanatory view of an assembling  
5 jig of distance holding members.

Fig. 6 is a cross-sectional view taken along a line D-D'  
in Fig. 5.

Fig. 7(a), Fig. 7(b) and Fig. 7(c) are schematic  
explanatory views of examples of a shape of a slit formed in  
10 the assembling jig shown in Fig. 5.

Fig. 8 is a schematic view showing a state in which the  
distance holding member is aligned with the slit shown in Fig.  
7(a) in place.

Fig. 9(a), Fig. 9(b) and Fig. 9(c) are schematic views  
15 for explaining the constitution of the back substrate to which  
the distance holding members are fixed.

Fig. 10(a) and Fig. 10(b) are schematic explanatory views  
of a constitutional example of the front substrate in the first  
embodiment of the present invention.

20 Fig. 11 is a cross-sectional view of an essential part  
of the display device in which the front substrate is assembled  
and integrally formed with the back substrate.

Fig. 12 is an enlarged view of an H portion in Fig. 11.

Fig. 13(a) and Fig. 13(b) are explanatory views of a third  
25 embodiment of the display device according to the present



invention.

Fig. 14 is a detailed explanatory view showing the back substrate and the structure for mounting the distance holding members in an erected manner shown in Fig. 13(a) and Fig. 13(b).

5        Fig. 15 is an enlarged view of a portion indicated by K in Fig. 14.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029]

10        Preferred embodiments of the present invention are explained in detail hereinafter in conjunction with drawings which show these embodiments.

[0030]

(Embodiment 1)

15        Fig. 3(a) and Fig. 3(b) are explanatory views of a first embodiment of a display device according to the present invention. Fig. 3(a) and Fig. 3(b) are served for schematically explaining the mounting structure of distance holding members, wherein Fig. 3(a) is a plan view of an essential part of a back substrate  
20        in a state that a front substrate is removed and Fig. 3(b) is a side view of the mounting structure as viewed in the direction of an arrow C in Fig. 3(a). In these drawings, numeral 9 indicates distance holding members and numerals used in Fig. 3(a) and Fig. 3(b) which are equal to numerals used in Fig. 2 indicate identical  
25        functional parts. The distance holding members 9 are arranged

between plate-member control electrodes 6.

[0031]

Further, Fig. 4 is an enlarged view of a D portion in Fig. 3(b). In Fig. 4, numeral 10 indicates a buffering/fixing material which is formed by mixing urethane resin as low-temperature decomposing foamed resin having high resiliency to a low melting glass as an adhesive. The urethane resin has a property to dissipate at a temperature of about 350°C. The buffering/fixing material 10 is applied onto the cathode lines 5 formed on the back substrate 1 and along and between the plate-member control electrodes 6. On the buffering/fixing material 10, one ends of the distance holding members 9 are erected using a jig similar to a jig which will be described later. In this embodiment, the buffering/fixing material 10 is arranged every three plate-like member control electrodes 6 corresponding to three unit pixels. These three unit pixels correspond to R, G, B which constitute 1 trio pixel of color display. However, positions where distance holding members 9 are mounted are not limited to the above positions.

20 [0032]

Although not shown in the drawing, another ends of the distance holding members 9 are brought into contact with the front substrate. Although the another ends of the distance holding members 9 may be fixed using only an adhesive such as frit glass or the like, it is needless to say that a similar

buffering/fixing material 10 can be interposed between the distance holding members 9 and the front substrate.

[0033]

Since the distance holding members 9 are joined to the back substrate 1 by way of the buffering/fixing material 10 in a state that the buffering/fixing material 10 is applied to the back substrate 10 side, different from a case in which only an adhesive is directly applied to the distance holding members 9, an applying quantity of the buffering/fixing material 10 can be made uniform. Accordingly, a large number of distance holding members 9 can be temporarily mounted in an erected manner by way of the buffering/fixing material 10 in a substantially equal quantity and over a substantially whole surface thereof. The buffering/fixing material 10 may be baked temporarily in this state.

[0034]

Fig. 5 is a schematic explanatory view of an assembling jig for distance holding members. Further, Fig. 6 is a cross-sectional view taken along a line D-D' in Fig. 5. In Fig. 5 and Fig. 6, numeral 11 indicates a lower-side jig, numeral 11a indicates projections, numeral 12 indicates an upper-side jig, and numeral 12a indicates stepped portions. Numerals which are equal to those in the previously-mentioned drawings indicate identical functional parts. In Fig. 5 and Fig. 6, the detailed constitution of the back substrate 1 is omitted. A plate-member

control electrode master plate 60 may be formed of plate-member control electrodes of an actual device, the plate-member control electrode master plate 60 is manufactured using a photo mask which is used for manufacturing the plate-member control electrodes 6.

[0035]

Fig. 7(a), Fig. 7(b) and Fig. 7(c) are schematic explanatory views showing examples of a shape of a slit formed in the assembling jig shown in Fig. 5, while Fig. 8 is a schematic view showing the state in which the distance holding member is aligned with the slit shown in Fig. 7(a) in place. In the lower-side jig 11 which constitutes the assembling jig of the present invention, slits 11b which enable the easy insertion of the thin distance holding members 9 and have upper portions thereof widened to provide the vertical arrangement of the distance holding members 9 are formed at a given interval. The slit 11b has a planar shape as shown in Fig. 7(a), Fig. 7(b) or Fig. 7(c). That is, the slit 11b has a wide opening portion 11b' at an end portion thereof. In inserting the distance holding member 9 into the slit 11b formed in the lower-side jig 11, as shown in Fig. 8, a corner of the distance holding member 9 is firstly aligned with and is inserted into the wide opening portion 11b' and, subsequently, the whole distance holding member 9 is inserted into the slit 11b as indicated by an arrow.

[0036]

By providing such a slit shape, it is possible to easily insert the distance holding member 9 into the slit 11b formed in the lower-side jig 11. Here, the position where the wide opening portion 11b' is formed in the slit 11b is not limited to the end portion of the slit 11b as shown in Fig. 7(a), Fig. 7(b) and Fig. 7(c) and the wide opening portion 11b' may be formed in a proper intermediate portion of the slit 11b.

[0037]

Returning to Fig. 5 and Fig. 6, the plate-member control electrode master plate 60 is mounted on projections 11a of the lower-side jig 11 and the upper-side jig 12 having a stepped portion 12a is mounted on the plate-member control electrode master plate 60 so as to hold the plate-member control electrode master plate 60. The plate-member control electrode master plate 60 has a periphery thereof fixed by a frame body. A large number of gaps 60a which correspond to an interval between strip-like electrode elements of an actual display device are formed in the plate-member control electrode master plate 60. The gaps 60a and the slits 11b formed in the lower-side jig 11 are aligned with each other in the z direction. The back substrate 1 to which the distance holding members 9 are temporarily fixed is mounted on the stepped portions 12a of the upper-side jig 12. Alternatively, it is possible to align and overlap the back substrate 1 on the stepped portions 12a of the upper-side jig 12 after arranging the distance holding members

9 as described below.

[0038]

Here, the distance holding members 9 are inserted into the slits 11b formed in the lower-side jig 11 in the mode explained in conjunction with Fig. 8 by allowing the distance holding members 9 to pass through the gaps 60a formed in the plate-member control electrode master plate 60. Further, with respect to the gaps 60a formed in the plate-member control electrode master plate 60, by slightly widening an insertion side of the distance holding member 9, the insertion of the distance holding member 9 is facilitated.

[0039]

A length of a distal end portion of the distance holding member 9 which is projected into the slit 11b formed in the lower-side jig 11 from the gap 60a formed in the plate-member control electrode master plate 60 is preferably set to  $1/4$  to  $1/3$  of the height of the distance holding member 9 to take the operability into consideration. In this type of field emission type display device, electrons are emitted with the intensity of an electric field of  $3\text{V}/\mu\text{m}$  and hence, provided that a distance of about 3mm is ensured between the plate-member control electrode 6 and the anode formed on the front substrate, it is possible to apply a high voltage of about 10kV. Accordingly, the above-mentioned projection quantity is set to a value slightly less than 1mm.

[0040]

The back substrate 1 is set to the jig as shown in Fig. 6 and subjected to a heat treatment while pressure is applied to the whole surface from above the back substrate 1. In this  
5 pressuring and heating treatment, due to a buffer action of urethane resin possessed by the buffering/fixing material 10, the pressure is uniformly applied to a plurality of the distance holding members 9 and, thereafter, the distance holding members 9 are fixed to the back substrate 1 due to melting and solidifying  
10 of frit glass contained in the buffering/fixing material 10. Simultaneously, the urethane resin is dissipated. Since the frit glass starts softening thereof at a temperature in the vicinity of 350°C, when the urethane resin is decomposed and loses the resiliency, the paste-like frit glass plays a role  
15 of a cushion material between the distance holding members 9 and the back substrate 1. Further, after performing the heating treatment at 450°C for about 30 minutes, the temperature is lowered so as to solidify the frit glass. Thereafter, the back substrate 1 to which one ends of the distance holding members  
20 9 are fixed is removed from the jig.

[0041]

Fig. 9(a), Fig. 9(b) and Fig. 9(c) are schematic views for explaining the constitution of the back substrate to which the distance holding members are fixed, wherein Fig. 9(a) is  
25 a plan view of the distance holding member, Fig. 9(b) is a view

as viewed from the direction of an arrow E in Fig. 9(a), and Fig. 9(c) is a view as viewed from the direction of an arrow F in Fig. 9(a). Although the buffering/fixing material 10 has a thickness of about 1mm before baking, in a state after solidifying shown in Fig. 9(a), Fig. 9(b) and Fig. 9(c), the thickness becomes about 0.1mm. In applying the buffering/fixing material 10 to the back substrate 1 side and mounting and fixing the distance holding members 9 on the back substrate 1, it is desirable to make an application area of the buffering/fixing material 10 broader than a cross section of the distance holding member 9.

[0042]

Fig. 10(a) and Fig. 10(b) are schematic explanatory views showing a constitutional example of the front substrate of the first embodiment of the present invention. Fig. 10(a) is a plan view and Fig. 10(b) is a cross-sectional view taken along a line G-G' in Fig. 10(a). Further, Fig. 11 is a cross-sectional view of an essential part of a display device in which a front substrate is integrally incorporated into a back substrate and Fig. 12 is an enlarged view of an H portion in Fig. 11. In Fig. 11 and Fig. 12, numeral 2 indicates the front substrate, numeral 13 indicates anodes, numeral 14 indicates phosphors and numeral 15 indicates a light shielding film (black matrix). The phosphors 14 constitute 1 trio pixel with an arrangement of red (R), green (G), and blue (B). Respective colors are defined



or partitioned by the black matrix 15. In this embodiment, a buffering/fixing material 10 for mounting distance holding members 9 is applied for every 1 trio pixel(R, G, B).

[0043]

5           For example, 1 trio pixel (R, G, B) of the phosphors 14 formed on the front substrate 2 is about 1mm, a gap of about 0.1mm may be provided between the phosphors (phosphor elements) of respective colors. Assuming that the distance holding member 9 having a thickness of about 50 $\mu$ m is mounted in the gap, to  
10 ensure the tolerance of 10 to 15 $\mu$ m for preventing the complete removal of the distance holding member 9 from an application region of the buffering/fixing material 10, it is desirable to set an application width of the buffering/fixing material 10 to 70 to 80 $\mu$ m. Further, it is desirable to set an application  
15 length of the buffering/fixing material 10 to about a length of the distance holding member 9 + 10mm provided that the alignment tolerance between the buffering/fixing material 10 and the distance holding member 9 is respectably 5mm at both ends.

[0044]

20           The front substrate 2 shown in Fig. 10 is laminated to the back substrate 1 to which the distance holding members 9 shown in Fig. 9 are fixed by way of an outer frame. The outer frame 3, the back substrate 1 and the front substrate 2 are adhered to each other using an adhesive 3a such as frit glass. Here,  
25 another ends of the distance holding members 9 provided to the

back substrate 1 shown in Fig. 9 are aligned with the buffering/fixing material 10 applied to the front substrate 2 side shown in Fig. 10. The average particle size of the phosphors formed on the front substrate 2 is about 2 to 5 $\mu$ m and a film thickness of the phosphors is about 10 $\mu$ m. The anode 13 which is formed on the front substrate 2 so as to cover the front substrate 2 is formed of, for example, a thin aluminum film (so-called metal back). A film thickness of the anode 13 is about 70nm to 100nm when the anode voltage is about 10kV.

10 [0045]

Fig. 11 is a schematic cross-sectional view showing an essential part of the display device formed by laminating the back substrate 1 and the front substrate 2 by way of the outer frame 3. Further, Fig. 12 is an enlarged view of a portion H in Fig. 11. One ends of the distance holding members 9 are mounted in an erected manner on the cathode lines 5 by way of the buffering/fixing material 10 between the neighboring plate-member control electrodes 6 formed on the back substrate 1, while another ends of the distance holding members 9 are held by the buffering/fixing material 10 provided to the anode 13 at positions of the black matrix 15 which are arranged between the phosphors 14 formed on the front substrate 2. In this constitutional example, the distance holding member 9 is mounted for every set of 1 trio color pixel (R, G, B). The mounting number of distance holding members 9 is calculated based on the

strength of the distance holding members 9. For example, when glass having a width of about 100 $\mu$ m is used, the distance holding members 9 may be arranged at an interval of 35mm, while when glass having a width of about 50 $\mu$ m is used, the distance holding members 9 may be arranged at an interval of 16mm.

[0046]

Heating is performed in this state while pressurizing the back substrate 1 and the front substrate 2 in opposing directions and, thereafter, the temperature is lowered so as to make the buffering/fixing material 10 fix the distance holding members 9 such that a uniform stress is applied between both substrates 1, 2. Thereafter, a display device is completed through a discharging step and an aging step. According to this embodiment, a large number of the distance holding members 9 can be mounted with high accuracy in the display device which arranges the plate-member control electrodes 6 between the back substrate 1 and the front substrate 2. Further, the stress attributed to the atmospheric pressure is uniformly applied to a large number of the distance holding members 9 and hence, the rupture of the distance holding members 9, the back substrate 1 or the front substrate 2 can be suppressed, whereby it is possible to obtain a highly reliable display device.

[0047]

(Embodiment 2)

In the above-mentioned first embodiment, as the

buffering/fixing material 10, the material which is prepared by mixing the adhesive to the highly resilient material made of foamed resin such as urethane resin which possesses high resiliency during assembling and dissipates in the baking process is used. A second embodiment of the present invention is characterized in that in place of the foamed resin which dissipates in the baking step, a buffering/fixing material which is prepared by mixing an adhesive to a resilient material made of a heat-resistant aramid-based resin fibers or the like which do not dissipate by heating at a high temperature in a short time is used.

[0048]

When the fibers made of heat-resistant aramid-based resin (product name: Kevlar or the like) is used as the resilient material, a sheet made of aramid-based resin fibers is placed between the distance holding members 9 and the back substrate 1 and/or the front substrate 2 and an adhesive such as frit glass having a low melting point is applied to a periphery and an upper portion thereof. Alternatively, a sheet made of aramid-based resin fibers in which the adhesive is impregnated is inserted between the distance holding members 9 and the back substrate 1 and/or the front substrate 2. Ensuing pressurizing and heat treatment are performed in the same manner as the previous embodiment. Due to the heat treatment, the aramid-based resin fibers remain at fixing portions as a reinforcing material.

[0049]

Also according to this embodiment, a large number of the distance holding members 9 can be mounted with high accuracy in the display device which arranges the plate-member control electrodes 6 between the back substrate 1 and the front substrate 2. Further, the stress attributed to the atmospheric pressure is uniformly applied to a large number of the distance holding members 9 and hence, the rupture of the distance holding members 9, the back substrate 1 or the front substrate 2 can be suppressed, whereby it is possible to obtain a highly reliable display device.

[0050]

(Embodiment 3)

Fig. 13 (a) and Fig. 13 (b) are explanatory views of a third embodiment of the display device according to the present invention. That is, Fig. 13 (a) and Fig. 13 (b) schematically explain the mounting structure of the distance holding members 9, wherein Fig. 13 (a) is a plan view of an essential part of a back substrate shown in a state that a front substrate is removed and Fig. 13 (b) is a cross-sectional view taken along a line I-I' in Fig. 13 (a). Further, Fig. 14 is a detailed explanatory view of the structure in which distance holding members 9 are mounted on the back substrate 1 in an erected manner shown in Fig. 13 (a) and Fig. 13 (b). Fig. 15 is an enlarged view of a portion indicated by K in Fig. 14.

[0051]

In the drawings, numeral 6d indicates electron passing apertures. Further, numerals which are equal to those in the above-mentioned embodiments indicate identical functional parts. In this embodiment, the distance holding members 9  
5 traverse the plate-member control electrodes 6 and are mounted at positions corresponding to the spaces between cathode lines 5. By mounting the distance holding members 9 such that the distance holding members 9 traverse the plate-member control electrodes 6, an interval between respective strip-like  
10 electrode elements which constitute the plate-member control electrodes 6 can be firmly held and hence, the displacement of position of the plate-member control electrode 6 and the occurrence of deformation such as twisting can be suppressed. In this embodiment, in the same manner as the first embodiment,  
15 as the buffering/fixing material 10, a material which is prepared by mixing an adhesive to a highly resilient material made of foamed resin such as urethane resin which exhibits high resiliency during assembling and dissipates in a baking step is used.

20 [0052]

Further, as shown in Fig. 14 and Fig. 15, it is desirable to adopt the following constitution. That is, a portion of the plate-member control electrode 6 which comes into contact with the distance holding member 9 is arranged between neighboring  
25 electron passing apertures 6d (one or a plural number) formed

in the plate-member control electrode 6 for every pixel and is arranged at a position where the plate-member control electrode 6 comes into contact with the back substrate 1 directly or by way of an insulation layer, whereby the plate-member control electrode 6 can be firmly pushed.

[0053]

In the plate-member control electrode 6 used in the display device of this embodiment, a recessed portion 6a is formed at a portion where the plate-member control electrode 6 crosses the cathode line 5, while the plate-member control electrode 6 comes into contact with a projection 6b which constitutes the above-mentioned recessed portion 6a. Further, a cut 6c is formed in the plate-member control electrode 6 in an opposite side (front substrate side) which corresponds to the projection 6b and one end of the distance holding member 9 is mounted in the cut 6c. It is preferable that by imparting a taper which opens upwardly to an inner wall of the cut 6c, when the pressure is applied to the distance holding member 9 from above, the position of the one end of the distance holding member 9 can be corrected by the taper. Further, the adhesive or the buffering/fixing material 10 which is applied to the front substrate 2 in this embodiment is provided on the black matrix 15 in the x direction in Fig 10.

[0054]

Then, the front substrate 2 is laminated to the back

substrate 1 and the pressure is applied uniformly from both substrate sides so as to make the pressure applied to the distance holding members 9 uniformly. The distance holding members 9 are fixed to the back substrate 1 by frit glass which is melted and solidified in an ensuing baking step. Here, the urethane resin dissipates in this baking step. In this manner, it is possible to mount the distance holding members 9 such that the stress is uniformly applied between the back substrate 1 and the front substrate 2 with respect to the pressure.

10 [0055]

Other constitutions and advantageous effects of this embodiment are substantially equal to those of the above-mentioned embodiments. Also according to this embodiment, a large number of the distance holding members 9 can be mounted with high accuracy in the display device which arranges the plate-member control electrodes 6 between the back substrate 1 and the front substrate 2. Further, the stress attributed to the atmospheric pressure is uniformly applied to a large number of the distance holding members 9 and hence, the rupture of the distance holding members 9, the back substrate 2 or the front substrate 1 can be suppressed, whereby it is possible to obtain a highly reliable display device.

[0056]

(Embodiment 4)

25 In the above-mentioned third embodiment, as the



buffering/fixing material 10, the material which is prepared by mixing the adhesive to the highly resilient material made of foamed resin such as urethane resin which possesses high resiliency during assembling and dissipates in the baking process is used. A fourth embodiment of the present invention is characterized in that in place of the foamed resin which dissipates in the baking step, a buffering/fixing material which is prepared by mixing an adhesive to a resilient material made of a heat-resistant aramid-based resin fibers or the like which do not dissipate by heating at a high temperature for a short time and remains as a reinforcing material is used.

[0057]

When the fibers made of heat-resistant aramid-based resin (product name: Kevlar or the like) is used as the resilient material, a sheet made of aramid-based resin fibers is placed between the distance holding members 9 and the back substrate 1 and/or the front substrate 2 and an adhesive such as frit glass having a low melting point is applied to a periphery and an upper portion thereof. Alternatively, a sheet made of aramid-based resin fibers in which the adhesive is impregnated is inserted between the distance holding members 9 and the back substrate 1 and/or the front substrate 2. Ensuing pressurizing and heat treatment are performed in the same manner as the previous embodiments. After the heat treatment, the aramid-based resin fibers remain as a reinforcing material.

[0058]

Also according to this embodiment, a large number of the distance holding members 9 can be mounted with high accuracy in the display device which arranges the plate-member control electrodes 6  
5 between the back substrate 1 and the front substrate 2. Further, the stress attributed to the atmospheric pressure is uniformly applied to a large number of the distance holding members 9 and hence, the rupture of the distance holding members 9, the back substrate 2 or the front substrate 1 can be suppressed, whereby  
10 it is possible to obtain a highly reliable display device.

[0059]

Further, in the above-mentioned second and fourth embodiments, in place of applying the adhesive such as frit glass after mounting the heat resistant resin fibers, it is also  
15 possible that the adhesive such as frit glass is firstly applied and, thereafter, the heat resistant resin fibers are mounted. In this case, heating is performed until the adhesive such as the frit glass is softened and, thereafter, pressurizing is performed.

20 [0060]

Further, in the above-mentioned respective embodiments, the explanation is mainly made with respect to cases in which the buffering/fixing material 10 is mounted on the back substrate 1 side and the front substrate 2 side. However, it may be possible  
25 to adopt the constitution in which the buffering/fixing material

10 is provided to only one of both substrates and only an adhesive is applied to another side.

[0061]

(Embodiment 5)

5            Since electrons emitted from the electron source of the cathode line 5 are not focused, when the buffering/fixing layer 10 or the adhesive layer at the front substrate 2 side having the phosphors is constituted of a completely insulated body, the electrons are charged in the buffering/fixing layer 10 or  
10 the adhesive layer thus giving rise to problems such as image retention and lowering of contrast. To avoid the occurrence of such charging, the specific resistance of about  $10^{11}$  to  $10^{12}$   $\Omega\cdot\text{cm}$  may be imparted to the buffering/fixing layer 10 or the adhesive layer. In this embodiment, a trace amount of conductive  
15 particles such as ATO is mixed into the buffering/fixing layer 10 or the adhesive layer. Further, a filler which controls a resistance value may be mixed into the conductive material.  
[0062]

            As the material which controls the resistance value, it  
20 is possible to use a silica coat liquid which is used for surface treatment of cathode ray tubes or the like. By heating the silica coat at a high temperature, the silica coat is dealcoholized by a sol-gel reaction thus forming polysiloxane coupling and the above-mentioned conductive particles are caught in the  
25 polysiloxane coupling whereby the silica coat can obtain stable

conductivity. Accordingly, it is possible to realize the countermeasure against charging of the front substrate 2 to which high voltage is applied. Further, by mixing a material having light shielding property to the above-mentioned buffering/fixing layer 10 or the adhesive layer, it is possible to form the buffering/fixing layer 10 or the adhesive layer in a black matrix BM applying step.

[0063]

Here, as a material of the black matrix BM, a material which is softened at 400°C to 450°C may be used. Further, to impart the light shielding property to the black matrix BM, oxide such as chromium oxide ( $\text{Cr}_2\text{O}_3$ ), iron oxide ( $\text{Fe}_2\text{O}_3$ ) or the like may be added to the black matrix BM. Accordingly, a step for forming the buffering/fixing layer 10 or the adhesive layer can be eliminated so that the number of manufacturing steps can be reduced and the manufacturing cost can be also reduced.

[0064]

According to this embodiment, a large number of the distance holding members 9 can be mounted with higher accuracy in the display device which arranges the plate-member control electrodes 6 between the back substrate 1 and the front substrate 2. Further, the stress attributed to the atmospheric pressure is uniformly applied to a large number of the distance holding members and hence, the rupture of the distance holding members 9, the back substrate 1 or the front substrate 2 can be suppressed,

whereby it is possible to obtain a highly reliable display device.

[0065]

As has been explained heretofore, according to typical  
embodiments of the present invention, in the display device which  
5 arranges the distance holding members between the back substrate  
having the plate-member control electrodes constituted of a large  
number of the parallel strip-like electrode elements and the  
front substrate having the phosphors and the anode, the stress  
applied to the distance holding members can be made substantially  
10 uniform and assembling of the distance holding members can be  
accurately performed whereby it is possible to provide the highly  
reliable display device by obviating the rupture of the distance  
holding members, the back substrate and the front substrate.

15